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## CONTENTS

The late blight disease of potatoes and its causal fungus in Canada ..... J. L. Howatt 185

Preliminary studies on corky ringspot of potato ..... R. E. Webb and E. S. Schultz 193

Accumulation of phenolic substances and ascorbic acid in potato tuber tissue upon injury and their possible role in disease resistance ..... Gestur Johnson and L. A. Schaal 200

### NEWS AND REVIEWS

Commission on industrial uses of farm products makes final report to Congress ..... 210

Nearly 30 years of peak efficiency at Long Island fertilizer company credited to engineering and equipment ..... 213

Notes on the potato crop in Canada ..... N. M. Parks 216

Call for papers for annual meeting ..... W. J. Hooker 217

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# THE LATE BLIGHT DISEASE OF POTATOES AND ITS CAUSAL FUNGUS IN CANADA[1]

J. L. Howatt[2]

## Introduction

The late blight disease caused by the fungus *Phytophthora infestans* (Mont.) de Bary occurs in every province of Canada but it is still relatively unimportant in Saskatchewan and Alberta. Late blight causes some damage almost every year in the Maritime Provinces and eastern Quebec but at irregular intervals it is troublesome in all the provinces of Canada. Under average conditions the disorder makes its appearance during the latter part of August or early in September. However, at frequent intervals the disease occurs much earlier, and in such seasons there may be considerable reduction in the yield of the affected plants. This reduction is due to the destruction of the foliage which may be appreciable early in mid-June on the Pacific Coast and about a month later in the Atlantic Provinces. Cool, wet seasons characterized by protracted periods of high humidity, or frequent rains which keep the foliage wet sufficiently long during daytime temperatures of 80° F. or less and cooler nights, favor the development of the disease. Such conditions most commonly prevail in coastal regions, around lake systems, or along river valleys. Certain locations, especially along the Atlantic seaboard, areas bordering on the coast, or exposed portions of bays and rivers adjacent to the open sea, are less favorable environments for the development of the disease than points farther inland that are less exposed to a sub-optimal condition. This condition is particularly noticeable in the Bay of Fundy and around the mouth of the St. Lawrence River where the limiting factor for disease development is apparently temperature rather than moisture. In certain inland regions heavy dews occur nightly when susceptible crops are maturing, and if this influence is sufficiently protracted it is highly conducive to the development of the late blight disease.

The losses occasioned by this disease are difficult to evaluate because of the many factors which complicate their estimation. Losses may be of two main types: (1) those affecting the yield, and (2) those affecting the edibility of the tubers. The greatest losses take place when blight destroys the vines before the tubers have fully developed. In this instance the tuber loss will be proportional to the vine destruction. On the other hand, if the vines are destroyed when the tubers are mature, little if any actual loss will be felt. However, if the potatoes are dug and exposed to infection from viable spores, heavy loss from tuber rot will result. When the vines are diseased the depth to which the tubers are covered, the type of soil, the rate of vine destruction and the presence of viable spores all profoundly affect the amount of rot which will develop. It is apparent that such factors make it difficult to fully assess the average loss experienced throughout Canada, but a conservative estimate places this loss at approximately 1,000,000 bushels of potatoes annually.

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Contribution No. 1598 from the Botany and Plant Pathology Division, Science Service, Canada Department of Agriculture, Ottawa, Ont.
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The uncertainty attending the control of this disease by fungicides, and the cost of materials and labor, prompted an endeavor to control it through plant breeding which for a short period of time appeared to alleviate the problem. However, the loss of essential available genes and the development of physiologic races of the fungus frustrated this design. Graham (2) has already stressed the importance of determining the type, distribution and fluctuation in the physiologic races of the late blight fungus. Once this knowledge has been acquired, plant breeders will be better informed as to the immediate requirements for breeding resistance to this disease.

The present contribution extends the knowledge concerning physiologic races and their distribution throughout Canada, and discusses some anomalies encountered in using the international series of genotypes.

## Materials and Methods

Late-blight-infected materials in the form of foliage, potato tubers, or tomato fruits were received from a great many locations throughout the provinces. The blight-infected material was given a number upon its reception and the collector's name, variety, source and date of collection were noted. When infected foliage was received it was usually incubated from 4 to 48 hours in the blight chambers until the fungus sporulated satisfactorily. These blight chambers (3) have been described previously. The state of infection was determined at the time the tubers were received and if infection was sufficiently well developed each tuber was sliced into four sections, placed in a dry, uncovered storage dish, 100 mm. in diameter and 80 mm. in depth, and incubated in the blight chambers under a polyethylene screen for 3 to 7 days or until the cut tuber surfaces showed abundant fructifications of the late blight fungus. Tubers which did not show a sufficient degree of infection when first inspected were incubated at room temperature until satisfactory in this regard, and then sliced and incubated in the blight chambers. In every case, infected tomato fruits were placed intact in the storage dishes and incubated in the .blight chambers until fruiting became visible. When the sporulation of any of the material had reached a satisfactory degree of development, it was made into a suspension by washing off the growth, with a proportionate amount of cold tap water, into the storage dish. Detached leaves of the international genotypes (1) extending from $R_1$ to $R_{3,4}$ and the Green Mountain variety were then inoculated by immersion in the spore suspension and transferred to covered trays lined with sphagnum moss and incubated at 65° F. or a slightly lower temperature in the blight chambers for an average period of 6 days. After this interval the leaves were examined by the unaided eye or through a 20-power lens, even the sparsest growth of the fungus being taken into account. When the necessity of using more complex genotypes was indicated the series was extended by subsequently employing the appropriate host plants. All cultures were treated as separate entities and great care was exercised in thoroughly cleansing the hands with soap and water before each inoculation and in observing other sanitary practices. After 1955, Black's international genotype $R_{1,3}$ was replaced by Mastenbrock's equivalent host.

## Results

In 1954, 490 collections of late blight material were received of which 311 collections were analyzed to disclose 467 isolates. Included in the collections were 33 potato varieties, namely: Green Mountain, Warba, Katahdin, Blue, Canso, Keswick, Golden, Bliss Triumph, McIntyre, Cowhorn, White Rose, Kennebec, Pontiac, Irish Cobbler, Sebago, Early Pinkeye, Teton, Canoga, Waseca, Snowdrift, Manota, Placid, Empire, Chenango, Norkota, Van Isle, White Cloud, Chippewa, Netted Gem, Red Warba, Ontario, Epicure, Cherokee, a number of potato seedlings and 42 unnamed tomato samples. All the early collections were received as infected vines, whereas material collected later was submitted in the form of infected tubers or tomato fruits. A considerable number of the total collection was lost because of bacterial soft rot infection which contaminated almost every sample. The survey data for this season are included in table 1.

Although the late blight disease was prevalent as a tuber rot in every province in 1954, the collections were confined to 6 provinces. Fourteen races appear to have been identified from field-grown material. In the country as a whole, race (4) predominated; race (1,4) was the second most prevalent race. A few collections of the races (1,2,4), (1,3,4) and (2,3,4) were made in Eastern Canada, particularly New Brunswick, where race (1,2,3,4) was also found at two widely separated locations.

Table 1.—*Distribution of races of Phytophthora infestans in 1954.*

| Race | Provinces | | | | | | |
|---|---|---|---|---|---|---|---|
| | P.E.I. | N.S. | N.B. | Que. | Man. | B.C. | Total |
| (0) | 1 | 0 | 2 | 0 | 0 | 0 | 3 |
| (1) | 5 | 1 | 7 | 5 | 0 | 2 | 20 |
| (2) | 2 | 1 | 16 | 5 | 0 | 1 | 25 |
| (3) | 6 | 0 | 21 | 4 | 2 | 1 | 34 |
| (4) | 44 | 1 | 79 | 39 | 2 | 12 | 177 |
| (1,2) | 0 | 0 | 2 | 5 | 0 | 0 | 7 |
| (1,3) | 6 | 0 | 33 | 12 | 0 | 5 | 56 |
| (1,4) | 6 | 3 | 33 | 35 | 0 | 0 | 77 |
| (2,4) | 1 | 0 | 12 | 7 | 0 | 0 | 20 |
| (3,4) | 0 | 0 | 27 | 13 | 0 | 1 | 41 |
| (1,2,4) | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| (1,3,4) | 0 | 0 | 2 | 1 | 0 | 0 | 3 |
| (2,3,4) | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| (1,2,3,4) | 0 | 0 | 2 | 0 | 0 | 0 | 2 |
| Total | 71 | 6 | 238 | 126 | 4 | 22 | 467 |

Although the late blight disease was reported in every province in 1955, the amount of tuber rot developed was slight. The number of samples submitted totaled 257 which included 22 varieties of potatoes, *viz.*: Green Mountain, Irish Cobbler, Keswick, Manota, Katahdin, Bliss Triumph, Kennebec, Sebago, Warba, Pontiac, Ontario, Sequoia, Canso, Cherokee, Teton, Arran Victory, Netted Gem, Menominee, Canus, Osseo, Houma, Pentland Ace, and 26 tomato varieties: Bonny Best, Earliana, Red Cloud, Amateur M-60, Mustang, Valiant, Early Hybrid, Norton Hybrid, Meteor, Abel, Calcross, Canadian Dwarf, Quebec No. 5, Early Chatham, Fireball,

Ponita, Monarch, Bounty, Bush Beefsteak, Early Stokesdale, Morden BB8, Carleton, Valnorth, Ottawa, Puck and Stokesdale. Three hundred and sixty isolates were identified from 220 of these samples. There was little evidence of bacterial soft rot infection in this material. The early potato samples were again submitted as infected vines. The data for 1955 are contained in table 2.

Inspection of the table shows that only 11 races were found in 7 provinces. Again the predominance of race (4) may be noted. A lesser number of the more complex races was found this year than in 1954 but this result may be due to sampling restrictions.

TABLE 2.—*Distribution of races of Phytophthora infestans in 1955.*

| Race | Provinces | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | P.E.I. | N.S. | N.B. | Que. | Man. | Sask. | B.C. | Total |
| (0) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| (1) | 0 | 2 | 2 | 1 | 0 | 0 | 1 | 6 |
| (2) | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 5 |
| (3) | 18 | 8 | 12 | 4 | 1 | 0 | 8 | 51 |
| (4) | 55 | 9 | 28 | 11 | 3 | 1 | 8 | 115 |
| (1,2) | 2 | 4 | 3 | 3 | 0 | 0 | 0 | 12 |
| (1,3) | 3 | 20 | 9 | 8 | 0 | 0 | 0 | 40 |
| (1,4) | 1 | 23 | 22 | 8 | 0 | 0 | 1 | 55 |
| (2,4) | 2 | 1 | 3 | 2 | 0 | 0 | 0 | 8 |
| (3,4) | 14 | 9 | 22 | 5 | 0 | 0 | 0 | 50 |
| (1,3,4) | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 3 |
| Total | 97 | 81 | 103 | 42 | 4 | 1 | 18 | 346 |

On the whole the late blight disease was of little importance during 1956. Co-operators contributed 234 samples of which 212 were analyzed. Bacterial soft rot was not important in the materials and the discrepancy between the numbers collected and analyzed was attributed to the absence of blight disease in the samples. This year's collections included the following potato varieties: Canso, Saco, Kennebec, Empire, Menominee, Keswick, Green Mountain, Katahdin, Osseo, Cherokee, Sebago, Netted Gem, Teton, Van Isle, Chippewa, Columbia Russett, Warba, Waseca, Sequoia, McIntyre, Rural Russett, Huinkul, the tomatoes Earliana and Early Bounty and 12 potato seedlings. A total of 314 isolates was identified, 102 of which were race (4) again making this the most common race found. Race (1,4) maintained its second position amongst the races identified.

Table 3 discloses that late blight races were identified from materials received from 9 provinces. Only 11 physiologic races of the organism were found, and of the more complex forms only race (1,3,4) was detected.

The results of the three separate surveys for physiologic races of *P. infestans* are brought together in table 4.

From table 4 it is seen that 14 races of the late blight organism have been found in the field in Canada, and that races (2,3) and (1,2,3) were never encountered. The common race in this country appears to be race (4) which accounted for 35 per cent of all the races found. It is interesting

TABLE 3.—*Distribution of races of Phytophthora infestans in 1956.*

| Race | Provinces | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P.E.I. | N.S. | N.B. | Que. | Ont. | Man. | Sask. | Alta. | B.C. | Total |
| (0) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| (1) | 1 | 8 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 12 |
| (2) | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| (3) | 7 | 7 | 6 | 4 | 6 | 0 | 1 | 1 | 1 | 33 |
| (4) | 31 | 10 | 30 | 15 | 8 | 2 | 2 | 1 | 3 | 102 |
| (1,2) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| (1,3) | 4 | 22 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 29 |
| (1,4) | 4 | 57 | 6 | 8 | 4 | 0 | 0 | 0 | 0 | 79 |
| (2,4) | 2 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 7 |
| (3,4) | 3 | 12 | 1 | 19 | 9 | 0 | 1 | 0 | 0 | 45 |
| (1,3,4) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Total | 53 | 124 | 45 | 48 | 32 | 2 | 4 | 2 | 4 | 314 |

to note that races with one or two factors for pathogenicity comprise 98.9 per cent of the races found and that races with three factors for pathogenicity occurred very rarely amounting to only 1.1 per cent of the total. No significant trend can be detected in the occurrence of the races, especially if consideration is given to the fact that apparent increases or decreases in race occurrence are due entirely to the varieties on which collections of late blight were made. For instance where race (1,4) appeared to increase in 1956 the result was due to a greater percentage of blight-resistant potatoes in the material sampled. Throughout the three-year period under review, difficulty was experienced in assigning the correct race designation to the genotyes affected. There was erratic registration of infection of the genotypes and in addition a difficulty of detecting the presence of only a few fructifications of the fungus on typical blight lesions. According to the international system, complex races such as (1,3,4) register only on their single genotypes $R_1$, $R_3$, $R_4$ and their combinations $R_{1,3}$, $R_{1,4}$, $R_{3,4}$, and $R_{1,3,4}$. Such is not always the case. For instance, a severe blight infection on genotype $R_4$ is often accompanied by a slight infection on genotype $R_3$. If a spore suspension from these infected leaves is used to inoculate a fresh series of the differential hosts, the blight may eventually occur in a severe form on genotype $R_3$ as well as on genotype $R_4$. Meanwhile it may or may not register as a light infection on genotype $R_{3,4}$, but on repeated inoculations to this host it may eventually appear as a severe infection on genotypes $R_3$, $R_4$ and $R_{3,4}$. These reactions serve to identify the causal form as race (3,4). However, this is not always so, because the fungus may eventually register only on genotypes $R_3$ and $R_4$ or it may confine itself to genotypes $R_4$ and $R_{3,4}$ without registering on genotype $R_3$. These anomalies have been encountered time and time again under controlled conditions, thus making it extremely difficult to assign with confidence the race designaton of a culture on the basis of only one determination on the genotypes. Furthermore, races are registered on a specific genotype that cannot be attacked by the forms indicated. For instance, blight resistant varieties such as Keswick or Kennebec sometimes register infections that are apparently due to races (2,4) or (3,4). Such races are

TABLE 4.—*Races of Phytophthora infestans found in the surveys 1954-1956.*

| Race | 1954 | | 1955 | | 1956 | | Aggregate 1954-56 | |
|---|---|---|---|---|---|---|---|---|
| | Number Found | Per cent Total | Number Found | Per cent Total | Number Found | Per cent Total | Number Found | Per cent Total |
| (0) | 3 | 0.6 | 1 | 0.2 | .. | .. | 4 | 0.3 |
| (1) | 20 | 4.3 | 6 | 1.7 | 12 | 3.7 | 38 | 3.4 |
| (2) | 25 | 5.4 | 5 | 1.5 | 4 | 1.3 | 34 | 3.0 |
| (3) | 34 | 7.3 | 51 | 14.7 | 33 | 11.0 | 118 | 10.5 |
| (4) | 177 | 38.0 | 115 | 33.2 | 102 | 32.4 | 394 | 35.0 |
| (1,2) | 7 | 1.5 | 12 | 3.5 | 1 | 0.3 | 20 | 1.8 |
| (1,3) | 56 | 12.0 | 40 | 11.6 | 29 | 9.2 | 125 | 11.0 |
| (1,4) | 77 | 16.5 | 55 | 15.9 | 79 | 25.3 | 211 | 18.8 |
| (2,3) | .. | .. | .. | .. | .. | .. | .. | .. |
| (2,4) | 20 | 4.3 | 8 | 2.3 | 7 | 2.2 | 35 | 3.1 |
| (3,4) | 41 | 8.7 | 50 | 14.5 | 45 | 14.3 | 136 | 12.0 |
| (1,2,3) | .. | .. | .. | .. | .. | .. | .. | .. |
| (1,2,4) | 1 | 0.2 | .. | .. | .. | .. | 1 | 0.1 |
| (1,3,4) | 3 | 0.6 | 3 | 0.9 | 2 | 0.6 | 8 | 0.7 |
| (2,3,4) | 1 | 0.2 | .. | .. | .. | .. | 1 | 0.1 |
| (1,2,3,4) | 2 | 0.4 | .. | .. | .. | .. | 2 | 0.2 |
| Total | 467 | | 346 | | 314 | | 1127 | |

TABLE 5.—*Anomalous registration of five races of Phytophthora infestans on specific genotypes.*

| Race | (1,2) | | | (1,3) | | | (1,4) | | | (2,4) | | | (3,4) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotypes Attacked | 1 | 2 | 12 | 1 | 3 | 13 | 1 | 4 | 14 | 2 | 4 | 24 | 3 | 4 | 34 |
| 1954 | 5 | 0 | 5 | 11 | 30 | 56 | 68 | 68 | 75 | 4 | 17 | 20 | 20 | 37 | 40 |
| 1955 | 11 | 0 | 12 | 34 | 29 | 39 | 53 | 54 | 54 | 1 | 7 | 8 | 42 | 50 | 50 |
| 1956 | 1 | 0 | 1 | 31 | 11 | 32 | 78 | 80 | 80 | 1 | 7 | 7 | 34 | 46 | 46 |
| Aggregate | 17 | 0 | 18 | 76 | 70 | 127 | 199 | 202 | 209 | 6 | 31 | 35 | 96 | 133 | 136 |

incapable of attacking these varieties and in these instances extrapolation to the most likely pathogenic forms (1,2,4) or (1,3,4) would seem to be the proper solution. Table 5 shows the findings in this respect over the three-year period for the five races (1,2), (1,3), (1,4), (2,4) and (3,4).

This table shows that race (1,4) is relatively free of the defects mentioned. All the remaining races, however, show some irregularity in registering consistently on the genotypes capable of being attacked.

## Discussion

The late blight disease of potatoes occurs in Canada from Newfoundland to British Columbia where it varies in intensity from year to year in an irregular portion of territory extending from the Canadian boundary northward to 50° latitude in the east and an extreme of 53° latitude in the west. The disease is usually, but not always, associated with the culture of the potato except in the far northwest. The causal fungus is essentially perpetuated in mycelial form in overwintered tubers that are eventually either planted or discarded in an outdoor cull pile. There is little if any evidence available that the fungus perpetuates itself by air-borne sporangia from the south or by oospores. Over the range of its occurrence, surveys have revealed the prevalence of numerous races of the fungus, the greatest number and most complex races of which occur in Eastern Canada where potato production is more intensified and blight-resistant varieties more widely planted.

Moreover, these surveys have shown that numerous races of blight are found on the same potato host in the field, and that the existence of race (0) and simple forms are masked by complex races. It has been found impossible to establish a vigorous race (1,3) from the infected genotype, and the registration of this race on Mastenbroek's genotype $R_{1,3}$ appears to be as unsatisfactory as the original international genotype in this respect. A uniform system of reading the infected genotypes was adopted throughout this investigation and no attempt was made to extrapolate the results to the most likely race. This decision has resulted in obvious errors. On the basis of the evidence, however, it appears that some complex races are more prevalent than are recorded in these investigations.

All the blight-resistant varieties that were released on this continent in recent years succumbed to the disease shortly after their introduction. All the new commercial varieties are susceptible to race (1) and any of the races having this component. The present work has shown that races of this race group are widespread in Canada. These surveys indicate the degree of resistance a potato variety must possess in order to withstand attack by the known races of the late blight fungus.

## Summary

The presence of the late blight disease of potatoes in Canada is discussed and factors are mentioned which affect the prevalence of this disease.

Surveys conducted in the period 1954-1956 yielded 1127 isolates of *P. infestans* which may be grouped into 14 races occurring in nine provinces.

The greatest number and the most complex races of *P. infestans* have been found in Eastern Canada and the least number in this regard in the Prairie Provinces.

The common race of the late blight fungus found appears to be race (4). Race (1,4) is also widely distributed.

It has been shown that the international genotypes cannot always be relied upon to register in one determination the correct race, and certain races often behaved in an erratic way on specific genotypes.

The basic value of surveying for races of *P. infestans* is stressed.

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# PRELIMINARY STUDIES ON CORKY RINGSPOT OF POTATO[1]

R. E. Webb and E. S. Schultz[2]

Corky ringspot of potato tubers (Figure 1) was described and illustrated by Eddins and his associates (*2*) from the vicinity of Hastings, Florida, in 1946. Although this disease (sprain, internal rust spot, Kringerigheid, Eisenfleckigheit, Buntfleckigheit, Pfropfenbildung, and malodie des tache en couronne) occurs in Europe, Dutch East Indies, and South Africa, it is doubtful whether corky ringspot was found before 1946 in the United States (*2*). The disease is apparently confined to the Hastings area and appears to be associated with certain soil types, which are underlain by an impervious hard pan (*6*).

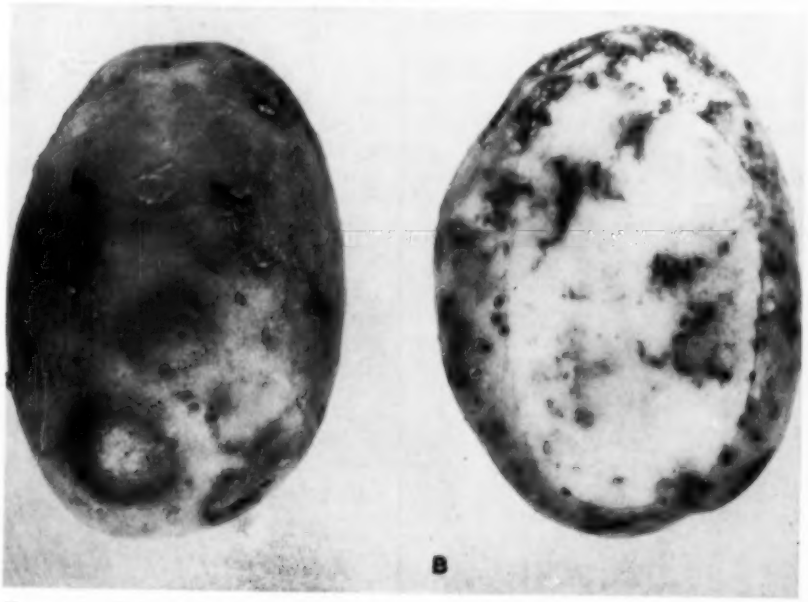


Figure 1.—Tubers of Sebago affected with corky ringspot: Left, Surface lesions; B, subsurface necrotic areas.

In 1946, affected tubers were observed from fields on 3 farms in the Hastings area. Some of these fields had been continuously cropped to potatoes for more than 25 years (*2*). In 1950 the disease was found in tubers from 5 additional farms (*4*). Although the disease does not seem to move rapidly from field to field, its erratic occurrence from year to year makes it difficult to ascertain its means of spread and distribution.

According to Atanasoff (*1*), as a rule, corky ringspot is of minor

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economic importance. Only in certain soils and in certain years does the disease appear in epidemic proportions. Under conditions favorable for the development of the disease, 50 to 100 per cent of the tubers my be affected. Eddins (5, 8) indicated that corky ringspot may be absent or nearly so in tubers from fields which had produced severely affected crops in previous years.

The causal agent of corky ringspot has not been definitely determined. Quanjer (9) classified the disease as being caused by a virus. Atanasoff (1) induced the disease in healthy tubers through grafts from affected ones. Rozendaal (10) and Rozendaal and van der Want (11) indicated that symptoms induced in tubers by the potato stem-mottle disease, which is apparently soil-borne, are similar to those of sprain (corky ringspot) and that perhaps they are more or less related types of diseases. However, Eddins (3, 6, 7) planted affected tubers on disease-free soil for a number of years and concluded that the causal agent is not transmitted through seed tubers to the new crop.

Over a period of years Eddins (3, 4, 5, 6, 7) apparently did not observe abnormal plant growth associated with corky ringspot in plants produced from affected tubers or in infested soil.

The authors have observed dwarfing, mottling, and some necrosis in plants grown from diseased tubers and have evidence of the communicable nature of the causal agent in affected seed tubers. This article presents the results of preliminary investigations on corky ringspot.

## Prevalence of Corky Ringspot

In mid-April of 1956, A. H. Eddins, in charge of the Potato Investigations Laboratory, Hastings, Florida, sent a quantity of corky-ringspot-affected Sebago tubers to Beltsville, Maryland. Shortly after the arrival of the diseased material, 10 whole tubers and 15 seedpieces from 3 other tubers were planted under controlled conditions for observation. Seedpieces from each tuber were planted separately so that each could be identified with its parent tuber. The remaining tubers were stored at 40° F. for planting in the fall. Three whole tubers and 26 seedpieces from 6 affected tubers were planted in sterilized soil in October, but inadvertently the seedpieces were not kept separate.

Precautions were taken to prevent spread of the causal agent or agents in used soil and by insects.

The results of the spring planting are shown in table 1. Three of the whole tubers produced some moderately dwarfed stalks, which were generally yellowish in color. The leaves of affected plants were dwarfed, malformed, and slightly rolled. Yellowish, blotchy areas occurred irregularly in affected leaves. Of the 15 seedpieces from the 3 diseased tubers, 4 decayed and did not produce plants. The 4 surviving seedpieces from tuber 1 produced apparently healthy plants. (Figure 2, A). All 5 seedpieces from tuber 2 germinated and produced single plants (2 healthy and 3 diseased). Two of the 3 diseased plants were severely dwarfed and chlorotic. The leaves were small, deformed, leathery, and mottled with yellow blotches (Figure 3). Some small necrotic spotting occurred in the affected leaves. The third plant from tuber 2 was only moderately dwarfed, and leaf necrosis was not observed. Three seedpieces of tuber 3 decayed. One of

TABLE 1.—*Plants produced by Sebago potato tubers affected with corky ringspot, when planted in April and October 1956.*

| Planting and Part Planted | Number Planted | Number Germinated[1] | Number of Plants Produced | |
|---|---|---|---|---|
| | | | Healthy | Diseased |
| April Planting: | | | | |
| Whole Tubers | 10 | 10 | 7 | 3[2] |
| Seedpieces from — | | | | |
| Tuber 1 | 5 | 4 | 4 | 0 |
| Tuber 2 | 5 | 5 | 2 | 3 |
| Tuber 3 | 5 | 2 | 1 | 1 |
| October Planting: | | | | |
| Whole Tubers | 3 | 3 | 2 | 1[3] |
| Seedpieces | 26[4] | 14 | 8 | 6 |

[1]Seedpiece that did not germinate, decayed.
[2]Some stalks not affected.
[3]Plant with 2 stalks.
[4]From 6 tubers not kept separate.

FIGURE 2.—Plants grown from corky-ringspot-affected Sebago tubers. A, Apparently healthy plant; B, healthy and diseased plants growing from the same seedpiece.

FIGURE 3.—Diseased plant of Sebago growing from an affected seedpiece.

the 2 plants produced from the surviving seedpieces was apparently healthy. The other one showed similar symptoms to those produced by seedpieces from tuber 2.

In the October planting (Table 1) one of the whole tubers produced 2 stalks which developed systemic foliar necrosis about 2 weeks after emergence. Ultimately, necrotic stem-streaking was evident, particularly near and in the nodes. Finally the apical buds were killed and the stalks died. Other plants produced from the diseased tubers were apparently healthy.

Eleven of the 26 seedpieces from the 6 affected tubers decayed and

failed to produce plants. Six seedpieces produced plants showing variable dwarfing, leaf malformation, leatheriness, and chlorotic mottling with yellowish blotchy areas, and some leaf and stem necrosis. A diseased and an apparently healthy stalk were produced by one seedpiece (Figure 2, B). Healthy plants were produced by 8 seedpieces from diseased tubers.

### Symptoms in Tubers from Diseased Plants

Tubers harvested from the diseased plants grown in the spring were small, and all but 5 had become mummified. One of the 5 showed internal symptoms similar to those characteristic of corky ringspot. When they were planted in October, only 1 tuber germinated, and the plant was apparently healthy. The ungerminated tubers were dug up for examination. Three had rotted and one was just beginning to germinate. This tuber was cut in half, and small necrotic spots were present in the flesh. Plants grown from the 2 halves were apparently healthy.

Seven tubers were harvested from 3 diseased plants grown in the fall. Two of these tubers showed considerable skin cracking and necrosis (Figure 4,B). Subepidermal necrosis was observed through the skin of one tuber (Figure 4,A). Both tubers showed necrotic areas in the flesh (Figure 4,C). A small tuber produced on a partially diseased plant is shown in figure 5.

### Transmission Studies from Diseased Plants

A moderately virulent strain of virus X was identified by inoculations to *Datura stramonium* L. from both diseased and apparently healthy plants produced by tubers of Sebago affected with corky ringspot. Inoculations from affected plants to diagnostic hosts indicated that viruses A, Y, and S were not causal agents. Differential reactions of plants of Sebago affected with virus X; S 41956 (immune from virus X); and Saco (immune from viruses A, X, and S) when grafted with scions from plants produced by corky-ringspot-affected tubers indicated that 1 or more viruses were present in affected plants.

### Summmary

Tubers of the Sebago variety affected with corky ringspot were planted in the greenhouse at Beltsville, Maryland. Most plants produced by these tubers were apparently healthy. Plants produced by 4 whole tubers and 9 seedpieces were moderately to severely dwarfed. The leaves of affected plants were small, deformed, leathery and mottled with yellowish blotches. Small, necrotic lesions occurred in the leaves of some affected plants. Necrotic stem-streaking, particularly in and near the nodes of some plants, was observed. Two plants developed systemic foliar and stem necrosis and later died. Both diseased and healthy plants were produced by the affected tubers, and a healthy and diseased plant were grown from the same seedpiece.

Tubers produced by diseased plants from affected tubers showed skin cracking and brown necrotic areas which extended from the surface to deep in the flesh. Subepidermal necrotic areas were visible through the skin. Necrotic areas occurred throughout the tuber flesh.

Transmission studies indicated that one or more unidentified viruses were present in diseased plants grown from tubers affected with corky ringspot.

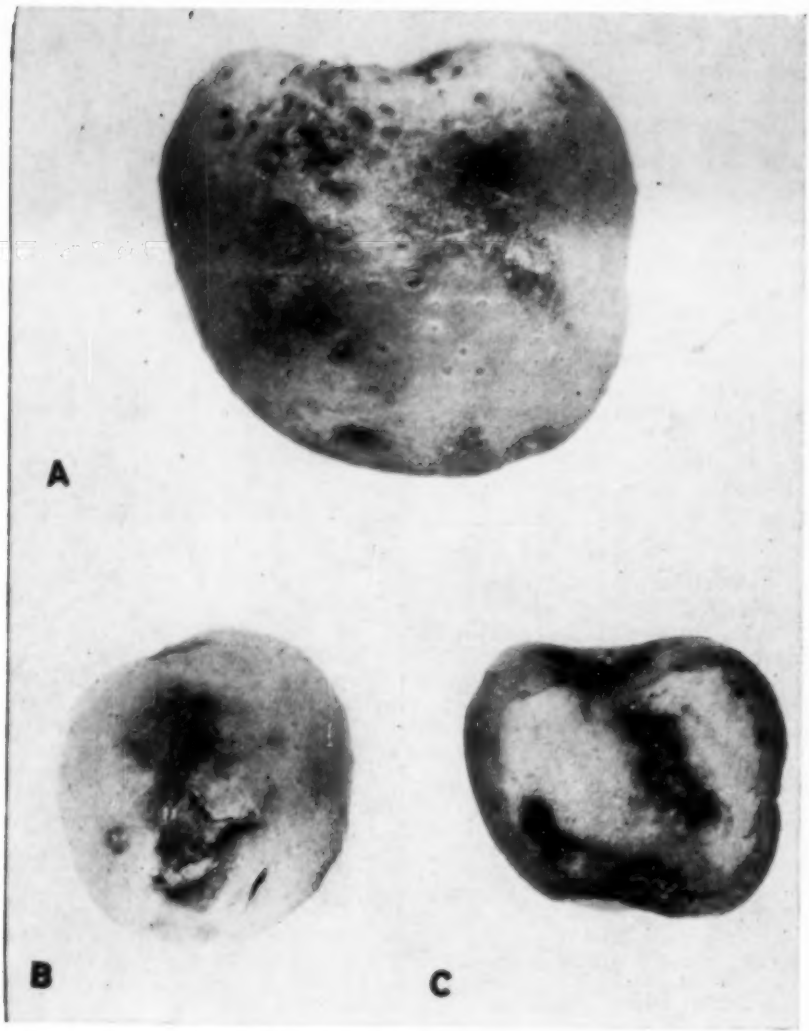


FIGURE 4.—Tubers produced by diseased Sebago plants grown from affected tubers: A, Surface view of subepidermal corky lessions; B, skin cracking and surface necrotic areas; C, brown necrotic areas in the tuber.

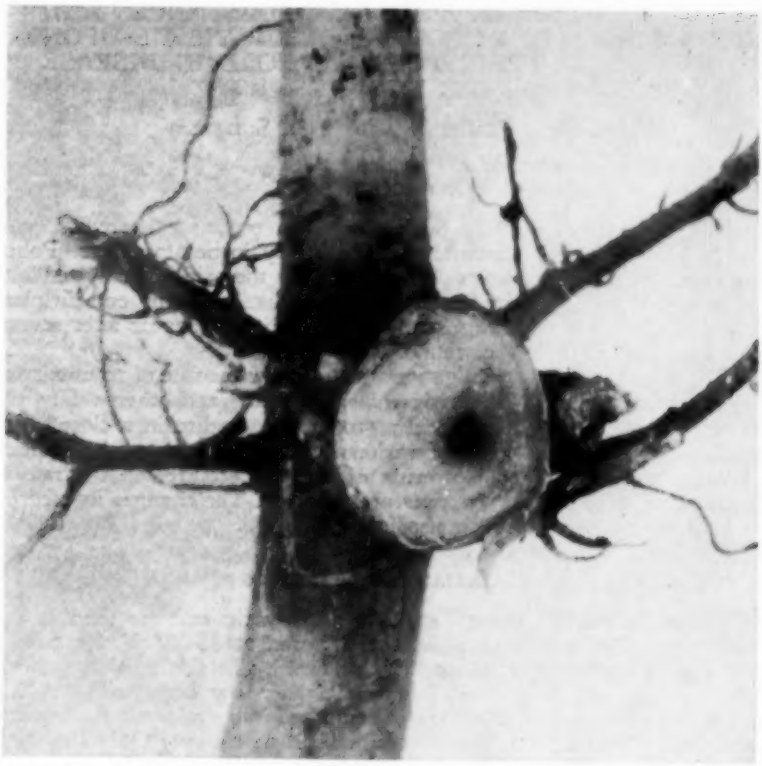

FIGURE 5.—Tubers produced on a diseased plant of Sebago showing an internal brown necrotic spot.

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# ACCUMULATION OF PHENOLIC SUBSTANCES AND ASCORBIC ACID IN POTATO TUBER TISSUE UPON INJURY AND THEIR POSSIBLE ROLE IN DISEASE RESISTANCE[1]

GESTUR JOHNSON AND L. A. SCHAAL[2]

## INTRODUCTION

In a previous publication the authors (3) reported that chlorogenic acid tends to accumulate around a tissue injury in potato tubers. Politis (8) made similar observations. He showed that the acid not only tends to localize adjacent to suberized membranes but that following cuts in plant tissues, which do not normally contain the acid, it will appear after several days in cells adjacent to the wound.

The purpose of this investigation was to follow the rate of accumulation of phenolic substances, particularly chlorogenic acid and other o-dihydricphenols, in potato tuber slices held at room temperature in a closed high humidity chamber. The effects of various treatments, such as the addition of tyrosinase inhibitors and lowering of the temperature, on the rate of accumulation of phenolic substances are reported. The changes in ascorbic acid content of the slices were also followed.

## MATERIALS AND METHODS

Russet Burbank, Triumph and Kennebec varieties were used in this investigation. The tubers used had been stored at 35-38° F. for 6 to 7 months. The tubers were selected for uniformity in size so that uniform slices could be obtained. The tubers were peeled by hand with a "Nee-Action" vegetable peeler. They were then sliced into uniformly thick slices, 3 mm. in thickness, by a Hobart mechanical meat slicer. Only the slices from the center part of the tuber were used. The Triumph slices were slightly larger in diameter than the Burbank slices.

For the experiments to determine the rate of accumulation of phenolic substance in the slices held at room temperature (75° F) sufficient samples were prepared to obtain four one-hundred gram samples of slices. One sample was immediately analyzed for total phenols by means of the Folin-Denis phenolic reagent. The method used was essentially that of Rosenblatt and Peluso (9). The sample was also analyzed for total o-dihydricphenols by the Arnow's (1) colorimetric procedure.

Each of the three remaining one-hundred gram samples was placed on an 8-mesh stainless steel screen in a 9 x 9 in. stainless steel baking pan and then covered with aluminum foil. The slices were placed on the screen in such a manner that they did not touch each other. Moistened paper towels were placed under the screen to maintain high humidity. One of the samples was stored for 2 days at room temperature (75° F) and then

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analyzed. The second sample was stored for four days and the third sample was held for six days. The slices did not lose weight during the storage holding periods.

The normal Kennebec tubers and those infected with aster yellows were only analyzed for phenolic substances immediately after slicing.

The 100 gram sample of slices was extracted with 300 grams of 95 per cent ethanol in a Waring Blender for 5 minutes. The total volume of the ethanol extract after making correction for the volume of the pulp was found to be 454 milliliters. Approximately 200 milliliters of the extract was filtered through a Whatman No. 12 fluted filter into a 250 milliliter Erlenmeyer flask.

### Determination of Total Phenols by Folin-Denis Reagent

One ml of the ethanol extract was pipetted into a 100 ml volumetric flask containing 70 ml of distilled water. Two ml of Folin-Denis reagent were added. After 2 to 3 min. of standing, 20 ml of 10 per cent $Na_2CO_3$ solution were added and the solution made to volume with distilled water. The blue color was allowed to develop for 1.5 hours and was read in an Evelyn Colorimeter using a 660 millimicron filter. In the blank sample for adjusting colorimeter to 100 per cent transmission, two ml of distilled water were substituted for the Folin-Denis reagent in the reaction mixture. Chlorogenic acid was used as a standard for calculating the total phenols. The optical density value of 0.132 for 0.1 mg chlorogenic acid per 100 ml was used.

The Folin-Denis reagent also measures tyrosine which was found to give the same amount of color with the reagent as chlorogenic acid. In the calculation of total phenols correction was made for ascorbic acid which also gives a blue color with Folin-Denis reagent.

### Determination of Ascorbic Acid

The ethanol extracts were analyzed for ascorbic acid by the indophenol dye method at the same time they were analyzed for total phenols by Folin-Denis reagent. The purpose of this analysis was to determine the ascorbic acid correction to be made in the determination of total phenols. Ascorbic acid (0.1 mg/100 ml) gave an optical density of 0.162 with the Folin-Denis reagent.

The above ascorbic acid analyses indicated that ascorbic acid also accumulates in tuber slices held at room temperature. For this reason the slices were analyzed each day during a four day storage period. The method used was essentially that of Loeffler and Ponting (6). A 0.25 per cent oxalic acid solution was used for the extraction of ascorbic acid.

### Analysis of o-Dihydricphenols

The total o-dihydricphenols were determined colorimetrically using the Arnow reagent (1) which is quite specific for these compounds. This reagent does not give a color with tyrosine.

One ml of the ethanol extract was pipetted into an Evelyn Colorimeter tube. The following reagents were then added: 1 ml of 0.5 N HCl, 1 ml of nitrate-molybdate reagent (10 gm of $NaNO_2$ and 10 gm of $Na_2MoO_4$

in 100 ml distilled water), 10 ml of distilled water and 2 ml 1 N NaOH. Thirty seconds after the addition of the alkali, the pink color produced was read in an Evelyn Colorimeter equipped with a 515 millimicron filter. In the blank sample used for the adjustment of the instrument reading to 100 per cent transmission, the Arnow's reagent was replaced by 1 ml of $H_2O$.

Optical density of 0.1 mg chlorogenic acid per 15 ml of the reaction mixture (optical density = 0.248) was used in the calculation of o-dihydricphenols.

The ethanol extracts of the slices held two, four and six days were diluted to twice their volume before sampling.

### Separation of Phenolic Substances by Paper Chromatography

A thirty ml aliquot of the ethanol extract was concentrated under reduced pressure to approximately 3 ml. The concentrate was quantitatively transferred by washing it into a 15 ml graduated centrifuge tube. The extract was made to a volume of 5 ml by the addition of 80 per cent ethanol. Any slight amount of insoluble residue was removed by centrifugation. Twelve $\mu$l of concentrated extract were used for the separation of the phenolic substances by paper chromatography and were applied by using six 2$\mu$l aliquots.

Both one and two dimensional paper chromatography were used. n-Butanol-acetic acid-water (40-10-20) was used as the developing solvent for one-dimensional and also as the first solvent followed by 5 per cent acetic acid in water as the second solvent for two-dimensional paper chromatography.

After air-drying the chromatograms were sprayed with Arnow reagent diluted with 1 part water and two parts ethanol to detect the o-dihydricphenols. The one-dimensional chromatograms were also sprayed with Folin-Denis reagent as described by Johnson and Schaal (3).

### Treatment of Whole and Sliced Tubers

The influence of various treatments on the rate of accumulation of the o-dihydricphenols in tuber slices were also investigated. The treatments included (1) 24 hour immersion of tubers in water before slicing, (2) dipping of slices for two minutes in sodium bisulfite-sodium chloride solution (500 ppm $SO_2$ and 1 per cent NaCl), (3) dipping slices in 0.25 per cent resorcinol solution.

### Results and Discussion

The rate of accumulation of phenolic substances in Russet Burbank and Triumph tuber slices held at room temperature (75° F) are shown in figures 1 and 2. The injury incurred upon cutting the tuber tissue stimulated the formation of phenolic substances in the slices. The ferric chloride spot test showed that these substances accumulate in cells adjacent to the wound. The data represented in figures 1 and 2 show that o-dihydricphenols, as indicated by curve #1, are the principal types of phenolic substances accumulating. Curve #2 shows the rate of accumulation of total phenols as measured by the Folin-Denis reagent. This reagent measures tyrosine as well as the o-dihydricphenols. Since chlorogenic acid

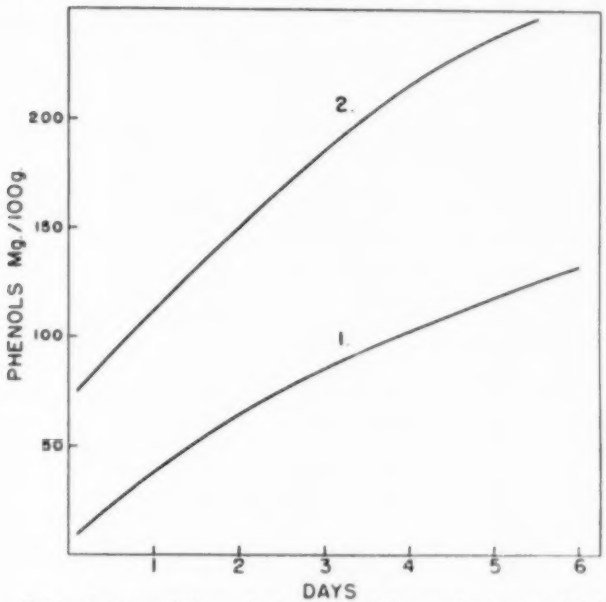


FIGURE 1.—Rate of accumulation of phenolic substances in Russet Burbank tuber slices, (1) Arnow reagent, (2) Folin-Denis reagent.

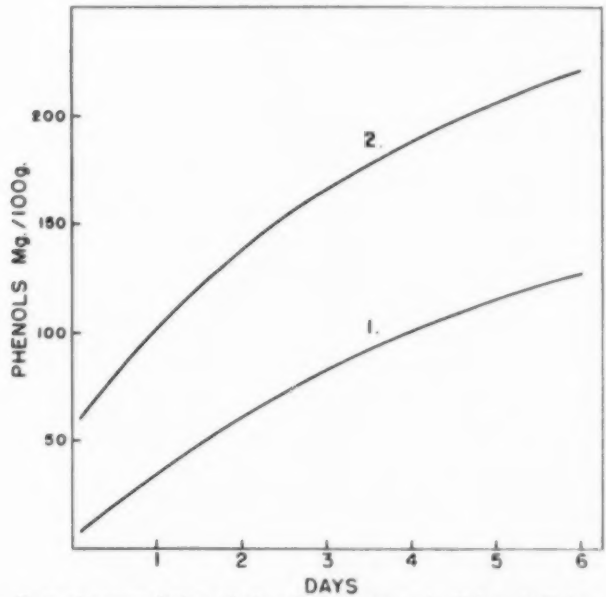


FIGURE 2.—Rate of accumulation of phenolic substances in Triumph Tuber slices, (1) Arnow reagent, (2) Folin-Denis reagent.

and tyrosine produce the same amount of color with the reagent, the difference between the amounts of phenolic substances determined by the two reagents is a fairly good measure of tyrosine. Tryptophan would also be included with tyrosine but since it gives much less color with the Folin-Denis reagent and is present in low concentration, the error caused by the presence of tryptopan would be small.

The fact that there was somewhat greater rate of accumulation of the phenolic substances measured by the Folin-Denis reagent would indicate some accumulation of tyrosine.

Since chlorogenic acid is the principal o-dihydricphenol in potato tubers, one would expect it to accumulate. Figure 3 represents two one-dimensional paper chromatograms of the concentrated extracts prepared from Russet Burbank slices held for 2, 4 and 6 days at room temperature (75° F). Chromatograms A and B which were sprayed with Arnow and Folin-Denis reagents, respectively, indicated that chlorogenic acid is the principal polyphenol accumulating. However, the two-dimensional chromatograms (Figure 4) of extract from Triumph and Russet Burbank slices showed not only the accumulation of chlorogenic acid but the accumulation of three other polyphenols, particularly the substance represented by spot 4. Spot 1 is chlorogenic acid. The nature of the polyphenols other than chlorogenic acid was not investigated except to determine that they were o-dihydricphenols.

Decreasing the temperature at which the slices were held greatly reduced the rate of accumulation of the polyphenolic substances. The comparative results for room temperature (75° F) and refrigerator temperature (35° F) are shown in figure 5. The lower rate at the lower temperature was apparently caused by the lower respiration rate. Other treatments which resulted in low rates of accumulation of phenolic substances in the tuber slices included (1) dipping of slices for two minutes in a 0.25 per cent resorcinol solution, (2) dipping slices in 0.03 per cent sodium bisulfite (500 ppm $SO_2$) — 1 per cent salt (NaCl) solution and (3) immersion of tubers in water (75° F) for 24 hours before slicing. The results of these treatments are shown in table 1.

The above treatments, and holding the slices at lower temperature, apparently have their effect by decreasing the rate of respiration. It would be logical to assume that respiration is necessary to furnish energy for the synthesis of the phenolic substances. Any treatment which decreases respiration rate would then affect the rate of accumulation of the phenolic substances.

Kennebec tubers showing pronounced net necrosis caused by aster yellows virus infection were found to give intense green color in the necrotic area upon testing with ferric chloride. This test indicated accumulations of orthodihyricphenols. The normal and diseased tubers were analyzed for total phenols (Folin-Denis) and o-dihydricphenols (Arnow reagent). The normal tuber contained 62 mg of total phenols and 4.9 mg of o-dihydricphenols per 100 grams. The diseased tuber contained 132 mg of total phenols per 100 grams and 52 milligrams of o-dihydricphenols per 100 grams. The concentrated extracts were also chromatographed. Although there was a definite increase in chlorogenic acid, the main increase was in the substance represented by spot No. 3, figure 4.

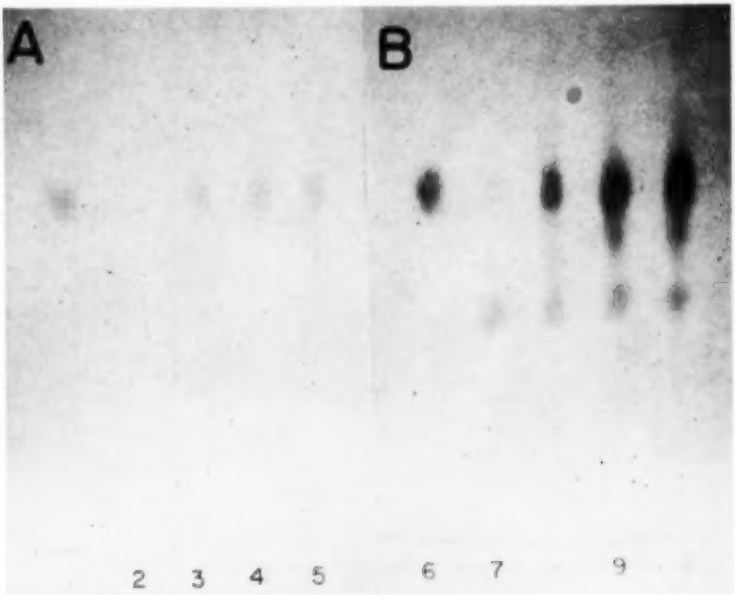


FIGURE 3.—Two one-dimensional ascending paper chromatograms of extracts from Russet Burbank tuber slices held at room temperature (75° F) 0, 2, 4 and 6 days. Chromatogram A sprayed with Arnow reagent and B sprayed with Folin-Denis reagent. Spots 1 and 6, chlorogenic acid; spots 2 and 7, 0 days; spots 3 and 8, 2 days; spots 4 and 9, 4 days; spots 5 and 10, 6 days.

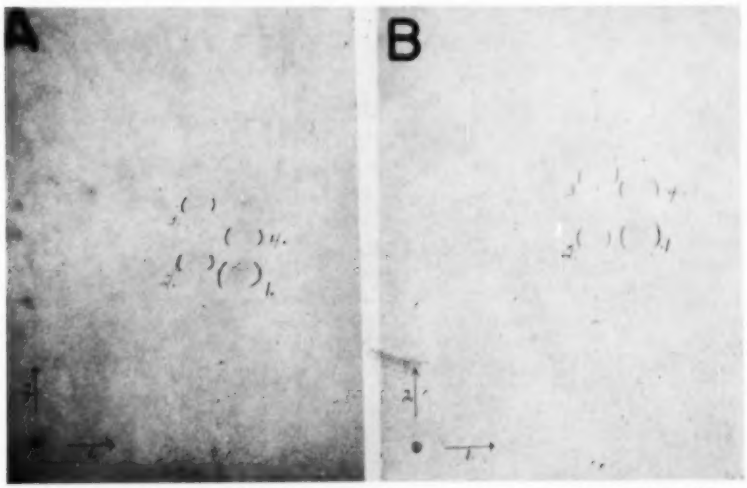


FIGURE 4.—Two dimensional paper chromatograms of extracts from tuber slices. A. Triumph, B. Russet Burbank, held for 4 days at room temperature (75° F). Chromatographed in (1) Butanol-acetic acid-water (40-10-20) and (2) 5 per cent acetic acid in water. Chromatograms were sprayed with Arnow reagent.

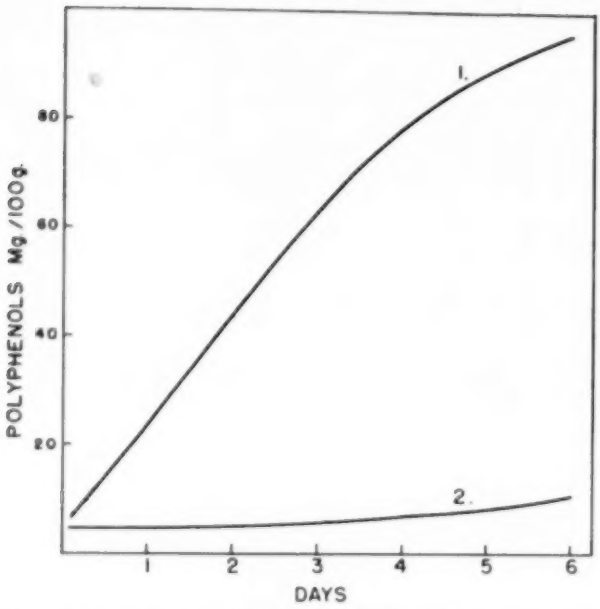


FIGURE 5.—Rate of accumulation of o-dihydricphenols in Russet Burbank tuber slices at (1) 75° F., (2) 35° F.

TABLE 1.—*Inhibitory effects of Resorcinol, Sodium Bisulfite and Immersion in water for 24 hours on the rate of accumulation of o-Dihydricphenols in Russet Burbank potato slices.*

| Days Held at Room Temperature | Resorcinol | | Sodium Bisulfite | | Immersion in Water—24 Hours | |
|---|---|---|---|---|---|---|
| | Control mg/100 g | Treated mg/100 g | Control mg/100 g | Treated mg/100 g | Control mg/100 g | Treated mg/100 g |
| 0 | 8.6 | 8.4 | 5.3 | 5.1 | 4.9 | 4.0 |
| 1 | | | | | 27.3 | 17.0 |
| 2 | 54.0 | 24.0 | 69.6 | 48.8 | 50.5 | 41.4 |
| 3 | | | | | | |
| 4 | | | 118.0 | 85.5 | | |
| 6 | | | | | | |

which is a chromatogram of Triumph and Burbank extracts. Only chlorogenic acid could be detected in the chromatogram of the extract from the normal Kennebec tuber and that only by fluorescence of the spot under ultraviolet light. The results obtained showed that the same phenolic substances accumulate upon pathological as upon mechanical injury to the tuber by cutting, although the relative amounts of each substance

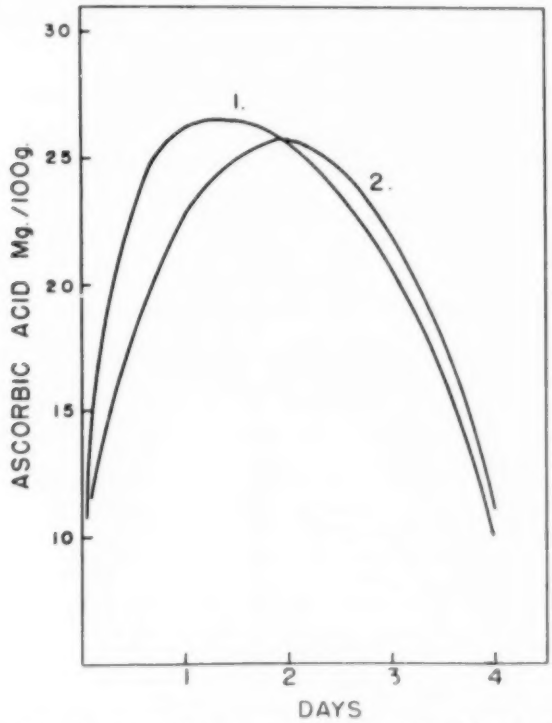


FIGURE 6.—Rate of accumulation of ascorbic acid in (1) Triumph, (2) Russet Burbank tuber slices.

may differ. In Russet Burbank and Bliss Triumph tubers infected with aster yellows, spot No. 4 appeared to accumulate more than spot No. 3. It should be emphasized that phenolic substances other than chlorogenic acid can accumulate in injured tissue.

Kuc, *et al.* (4) reported greater increases in chlorogenic acid and caffeic acid in potato slices inoculated with spore suspension of *Helminthosporium carbonum* than in slices not inoculated but incubated for some length of time at 22° C for 72 hours. Unlike chlorogenic acid, caffeic acid does not accumulate in cells adjacent to the cut surface. The increase in caffeic acid in tuber slices upon inoculation with *H. carbonum* as reported by Kuc (4) might be explained by the fact that it was probably formed by the enzymatic hydrolysis of chlorogenic acid by an esterase secreted by the organism.

## RELATION OF ACCUMULATION OF PHENOLIC SUBSTANCES TO DISEASE RESISTANCE

Since there appears to be very little difference between the rate of accumulation of phenolic substances upon injury in the scab-susceptible Triumph and the scab-resistant Russet Burbank varieties, indications are

that this phenomenon is not so important as the relative amounts of chlorogenic acid present in the periderm. However, the accumulation of polyphenols adjacent to the injury may be very important from the standpoint of other types of resistance as indicated by the work of Uritani (10) and Kuc, *et al* (4).

Uritani postulated that the accumulation of chlorogenic acid, caffeic acid, methyl caffeate, umbelliferone, scopoletin, ascorbic acid and ipomeamarone in sound sweet potato tissue adjacent to that rotted by *Ceratostomella fimbriata* was associated with resistance of sweet potato to the attack by that organism. Uritani also showed that respiratory enzymes of the above organism were inactivated during the oxidation of sweet potato polyphenols.

Since there is evidence that the accumulation of phenolic substances is involved in disease resistance, then any predisposing factor which would reduce the rate of synthesis of phenolic substances upon injury by reducing the rate of respiration would then increase the susceptibility of the tuber to certain diseases. Apparently suffocation such as that obtained upon immersion of tubers in water for 24 hours or longer can be a factor which could influence the rate of accumulation of phenolic substances in tubers and therefore make it more vulnerable to attack by certain organisms. Livingston (5) studying mechanisms of action of various predisposing agents on the bacterial soft rot susceptibility of potato tubers has shown that immersion of potato tubers in water by long periods will irreversibly interfere with the natural soft rot resistance mechanism of the tuber.

It is becoming more evident that phenolic compounds can be associated with plant disease resistance and immunity in at least three ways. (1) They can be present in the plant tissue prior to infection. Recently Barnes and Gerber (2) attributed the remarkable resistance to decay of osage orange wood to the presence of 2,3', 4,5' tetrahydroxystilbene. (2) They can be present in the plant tissue prior to infection but oxidation to quinones being necessary for inhibiting growth of the organism and/or stimulating suberization as in the case of scab resistance of potatoes. (3) They can accumulate in sound tissue adjacent to a mechanical or disease induced injury. In the case of the latter this could be an expression of a resistance mechanism on the part of the host in a host-parasite interaction. The oxidation state may be specific or non-specific for the disease organism.

## Accumulation of Ascorbic Acid

Ascorbic acid analysis of the ethanol extract was made to correct the error due to ascorbic acid in the analysis for total phenols by the Folin-Denis reagent. The results obtained indicated that ascorbic acid accumulated in the sound part of the tuber tissue, although it is actually oxidized in the damaged cells on the cut surface. The rate of accumulation of ascorbic acid was followed and the results are shown in figure 6. There was a rapid increase in ascorbic acid for the first two days. This increase was followed by a rapid decrease. Just why ascorbic acid accumulates is not known. It might possibly protect the sound tissue from quinones diffusing from the injured cells.

Upon the rapid decrease of the accumulated ascorbic acid, there is good reason to believe that dehydroascorbic acid and other oxidative break-down products of ascorbic acid will accumulate. No attempt was

made to determine these substances. However, autoxidized ascorbic acid was shown by Myrvik and Volk (*7*) to have certain antibacterial properties. They performed short term growth experiments which indicate that the enediol group had no antibacterial properties but that the oxidized enediol (diketone) produced immediate bacteriostatis. Their work indicates that if oxidized products of ascorbic acid can accumulate in injured plant tissue, there is a definite possibility that these substances can function in the resistance of plants to certain diseases.

## Summary

Chlorogenic acid and other o-dihydricphenols were found to accumulate rapidly in the area adjacent to the cut surface of potato tuber slices held at room temperature in a moist chamber.

The rate of accumulation was found to be decreased by: (1) holding the slices at lower temperature; (2) dipping the slices in resorcinol solution; (3) dipping slices in sodium bisulfite-sodium chloride solution; (4) immersion of whole tubers in water (room temperature) for 24 hours prior to slicing.

The same phenolic substances which accumulated in tuber slices were found to accumulate in necrotic areas of tubers infected with aster yellows.

Ascorbic acid was found to accumulate in tuber slices but rapidly decreased after the second day of holding at room temperature.

Several ways in which phenolic substances can function in the mechanism of disease resistance are discussed.

The possibility that the accumulation of oxidized products of ascorbic acid adjacent to infected tissue may play a role in disease resistance is also discussed.

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## NEWS AND REVIEWS

### COMMISSION ON INDUSTRIAL USES OF FARM PRODUCTS MAKES FINAL REPORT TO CONGRESS

The need for a dynamic and imaginative approach to farm-product utilization as a way of solving problems of farm surplus is emphasized throughout the final report to Congress made today (June 15) by the President's Commission on Increased Industrial Use of Agricultural Products.

The 250-page report completes the work of the five man bipartisan Commission directed by the 84th Congress to make recommendations for a long-range program to widen the industrial use of farm products — particularly those in surplus.

To carry out this assignment, Chairman J. Leroy Welsh of Omaha, Nebr. and Commission members received help from almost 200 of the country's top leaders in agriculture, industry, and science.

Members of the Commission beside Mr. Welsh include Karl D. Butler, Ithaca, N. Y.; George Henry Coppers, Englewood, N. J.; Charles R. Sayre, Scott, Miss.; and Frank J. Welch, Lexington, Ky. Executive Director of the Commission is Wheeler McMillen, Philadelphia, Pa.

Mr. McMillen commented that the group not only completed its job in its allotted time — less than 10 months — but will return to the U. S. Treasury about $20,000 of the $150,000 Congress appropriated for the study.

The Commission held its first meeting August 22, 1956. Its duties terminated today, June 15.

The group set out to find answers to the question: Can industrial markets absorb enough excess farm production to minimize — or possibly even eliminate — costly restrictions, supports, and surplus-disposal operations?

Here is its conclusion, spelled out in the final report: "The Commission believes the answer is an emphatic *Yes*, provided the necessary steps are taken to make possible and encourage such a development."

These necessary steps are presented in the report as the Commission's recommendations. They are: (1) Increase participation by public and private institutions in an effective research network. (2) Greatly expand basic research on use of farm products. (3) Increase use of grants, fellowships, and scholarships to increase the Nation's supply of scientists. (4) Place more emphasis on government-industry sharing of research costs. (5) Expand research and development work with new crops. (6) Make wider use of commercial-scale trials of new products. (7) Offer economic incentives to growers and processors to bridge the gap between research and established industrial uses of crops.

Three additional recommendations concern financing and administration:

The Commission urged at least a three-fold increase in funds for industrial utilization research in the U. S. Department of Agriculture. It recommended that in lieu of direct appropriations, 15 per cent of the annual gross receipts from customs revenues be allotted for the industrial utilization program.

For the administration of the program, two alternative recommendations were made:

The first would establish a five-member, non-partisan Agricultural Research and Industrial Board appointed by the President. This board would allocate funds, make contracts with research institutions, and direct and coordinate the program but would not engage in research.

The alternative plan would place the responsibility for the program in the U. S. Department of Agriculture, under a director with the rank of Assistant Secretary of Agriculture, in charge of research and education within the Department. The board would be appointed by the President but would be responsible to the Secretary of Agriculture.

The Commission pointed out that in making its recommendations it had in mind "the need to achieve effective results as promptly as possible, and to maintain and expand the excellent research operations of the Department of Agriculture and the Land-Grant Colleges and Experiment Stations, to make effective use of the talent and facilities of other institutions, and to add as little as possible to the structure of government."

The Commission's final report will be printed as a Senate document. Copies may be obtained from Members of Congress.

Two of the reports about white potatoes follow.

## WHITE POTATOES

Even in the short period of 12 years between 1940 and 1952, potato consumption in the U. S. dropped from 128 pounds per person to 100 pounds. Meanwhile there has been a marked change in the pattern of use. In 1940 only 3.2 million hundredweight of potatoes, or 2.1 per cent of total sales, were processed — 4/5 for potato chips, 1/5 for hash, stew, soup, flour. By 1955 the quantity processed had increased to 32.3 million hundredweight, or 17 per cent of sales — 23.6 million for potato chips, 8.7 million for frozen french fries, dehydrated potatoes, canned potatoes, hash, stews, soups, flour.

In 1942 2 million hundredweight of potatoes were used for starch, in 1950, 13.1 million, in 1956, 17.5 million. The quantity depends on the surplus situation, since this is a government-subsidized use. The starch is valued in the textile and paper industries, which would take 2 or 3 times as much as they can get.

Some 5 to 8 per cent of the crop is used each year for livestock feed.

The potato industry is confident that a materially enlarged research and development program would so expand the market that surpluses would disappear and it might even be necessary to increase production. For the next 5 to 10 years, food products and processes would be the most important. The growth in the sales of processed potatoes in the last 15 years is impressive, and undoubtedly many and better products could be created. Meanwhile active work should be underway to expand industrial utilization. Here, much emphasis should be given to fundamental research to discover many facts not now known about potato components, which like those of grain, should be adaptable to many uses.

Specific suggestions on research problems to increase the uses of white potatoes through industrial utilization and the expansion of the use of potato starch are presented here.

1. *Proposed use*: Industrial, food and feed products.
*The Problem*: To probe the fundamental nature of the potato through basic research that will provide the facts essential for developing new uses.
*Objectives of Research*: Very few of us really know or can even pronounce all the things there are in a potato — starch, hemicellulose, pentosans, oligosaccharides and reducing sugars, organic acids, carotenoids, lipoids, enzymes, pectine, amino acids, proteins, vitamins, flavonoids, minerals. Perhaps it is just as well. The fact is that this plain brown skin hides many tantalizing biological and chemical mysteries. They need to be much more thoroughly explored in order to lay all the facts on the table that are needed to put more potatoes in the same place. For instance:
Which of this complex array of substances are responsible for differences in processing and eating qualities? For flavor and odor? For mealiness or other texture characteristics? For the development of off-flavors, off-odors? For darkening and graying under certain conditions?
What is the relation of enzymes — and which enzymes — to the formation of undesirable green pigment and a bitter alkaloid near the surface? To discoloration in the center? To changes associated with sprouting? To the reversible transformation between sugars and starch in new potatoes? To the discoloration of sliced or peeled potatoes?
What in detail, is the molecular structure of potato starch? What are its reactions in oxidation, esterification, polymerization, and so on? How can the amylose molecules be economically separated from the amylopectin molecules? These are some of the questions that need to be answered to develop more effective methods of handling, storing, processing, and conversion than those now used.
*Relation to current or past research*: Potato starch is known to differ from cereal starches in molecular weight, granular size and phosphorus content. It is to these physical differences that we must look to find new markets. Basic investigations of the amino acids of the protein and the enzymes are being carried on. Effects of irradiation and sprout inhibitors, especially as they affect processing characteristics, are being investigated.
2. *Proposed use*: Starch for industrial products.
*The Problems*: To develop a wide range of new industrial uses for potato starch and flour.
*Objectives of Research*: The part of the potato that is of most use industrially is the starch. The whole potato converted into flour is also industrially useful. It contains protein and fiber in addition to starch. Some 150 million pounds of potato starch are now used annually by the paper and textile industries. This is a government-subsidized use, and the product comes from cull potatoes. These industries would like to get considerably more potato starch, which has unique properties.
Potato starch is adaptable to the same widely varied uses as is starch from grain, but they never have been systematically explored to see where this particular product might best fit. One of the essential preliminary steps is to develop processing methods for starch and flour that would reduce costs, give more uniform products, and permit adequate disposal of wastes. Another need is to find practical ways to convert cull potatoes to a stable form (as by dehydration or chemical treatment) so they could be held for later conversion into starch or livestock feed.

The potential uses for potato starch or flour that should be explored and tested include adhesives, sizing, and coating materials for textiles and paper; extenders to take the place of some of the cellulose in pulp for paper manufacture; and chemically modified starches (such as dialdehyde) for tanning materials, plastics, films, protective coatings, chemicals, and other major uses.

*Relation to current or past research*: Considerable research has been done at both Federal and State Experiment Station laboratories on improved methods of production and on uses of potato starch and flour with the main emphasis on food uses. Some progress has been made in the production of improved starches, but little effort has been put into the expansion of industrial uses of the starches.

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## NEARLY 30 YEARS OF PEAK EFFICIENCY AT LONG ISLAND FERTILIZER COMPANY CREDITED TO ENGINEERING AND EQUIPMENT

The Long Island Produce and Fertilizer Company, with its main plant and offices in Riverhead, Long Island, produces high-grade fertilizer for the major Suffolk County market where Long Island potatoes and cauliflower are the main crops of this agricultural county.

When potatoes are being planted in March and April, it is often necessary to work around-the-clock, processing 25 tons of fertilizer an hour in the Riverhead plant. September and October are the slowest months of the year for the company, as they are throughout the industry, and most major maintenance occurs at that time. Mixing and bagging are scheduled carefully so that it continues ten months a year, minimizing the seasonal layoffs that once were the plague of the fertilizer industry.

At the Riverhead plant, since the early 1930's, a one-ton capacity rotary dry batch mixer has been operating efficiently with a minimum of maintenance (Figure 1). Prior to 1943, it was used primarily for bagging operations; since that time, it has been utilized in the careful blending of fertilizer constituents with nitrogen solutions.

Three years ago, the first major maintenance problem on the Sturtevant mixer occurred — the inner drum, corroded and abraded beyond recall, was replaced. Aside from this action, only minor parts have needed repair. Scoops, which cascade the fertilizer components in a 180° arc, have needed intermittent replacement.

The Long Island Produce and Fertilizer Company's Riverhead operation was engineered and installed in the early 1930's by Sturtevant Mill Company of Boston, Massachusetts, manufacturer of the Sturtevant Rotary Dry Batch Mixer which has given such satisfactory service, and engineers and fabricators of the bucket elevator which conveys the ingredients into process. William Howland, plant superintendent, commenting on the plant operation, said the company has received "30 years of cooperation from Sturtevant. They never have refused to help when problems occur, and you know how many problems come up dealing with this stuff."

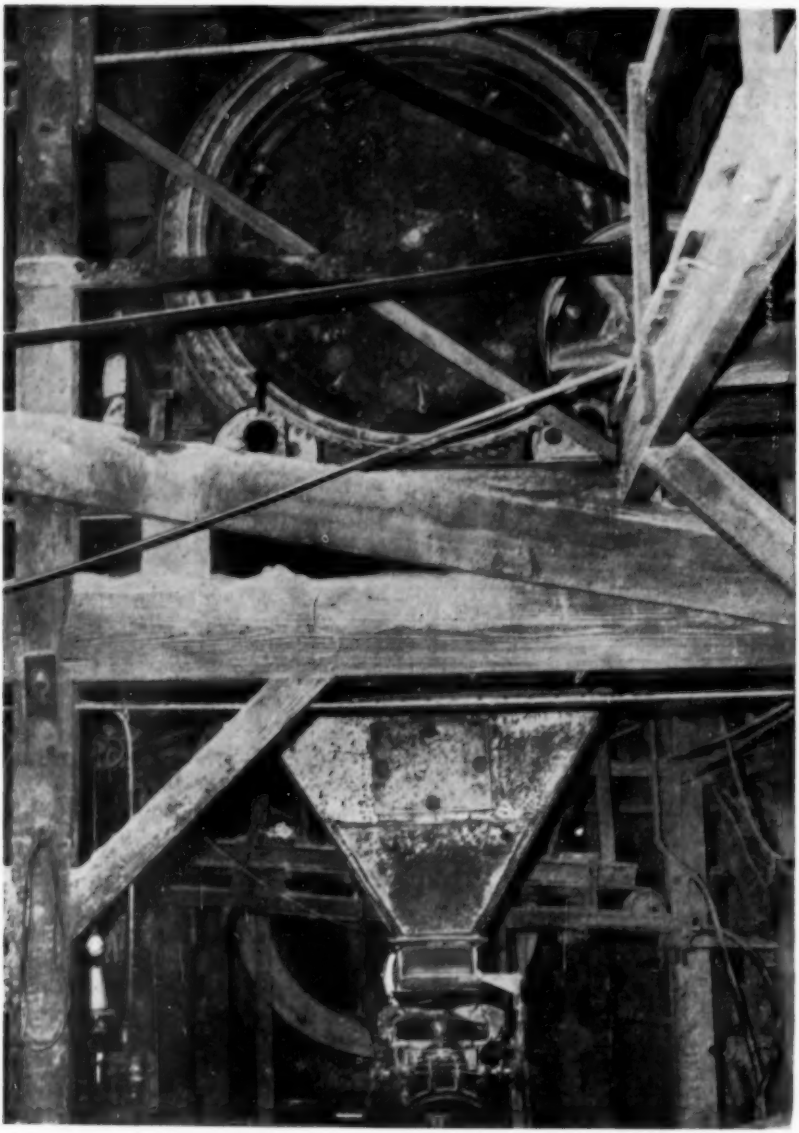

FIGURE 1.—Overall view of blending operations. At the top is one-ton rotary dry batch mixer. Below is discharge hopper from which blended material is carried into cooling stage.

Here's how the plant operates:

Ingredients come to the plant siding by rail or by truck from sources in New Jersey, Pennsylvania, Virginia and New Mexico. They are delivered, a ton batch at a time, to a Sturtevant bucket elevator, and are elevated two and a half stories to a breaker, thence through a vibrating screen and introduced into the mixer for a two or three minute blending operation, during which nitrogen solution is added. The fertilizer leaves the blending operation at a high temperature and is then channelled through a 25-foot cooler (Figure 2).

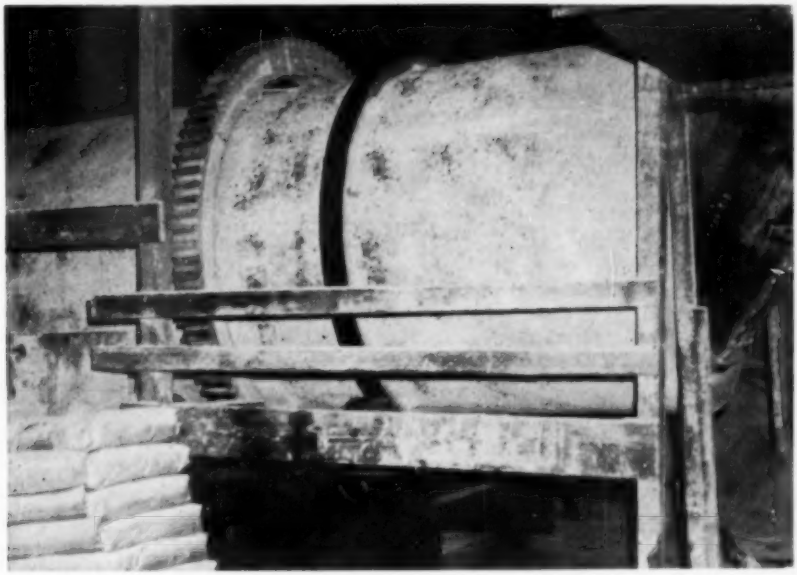

FIGURE 2.—Here fertilizer is cured and cooled. Blended material enters drum at high temperature, leaves unit about 20°F cooler

From the cooling operation, the fertilizer is discharged into stock piles for further curing and storage. After curing, the bulk fertilizer is reclaimed, screened and bagged for direct farm delivery or for branch warehouse storage (Figure 3).

Several formulations are produced to meet the requirements of specific crops. A quality control program is maintained by LIPCO and all fertilizers are inspected by the New York State Department of Agriculture and Markets.

Maintenance and cleaning problems are relatively minor. Corrosion that is inevitable is evident on the outsides of most of the plant units, but this is compensated for by heavier equipment design. As for equipment in the wholly-Sturtevant-engineered plant, Superintendent Howland said: "I wish we had as little trouble with other equipment as we do with the Sturtevant units."

FIGURE 3—After bagging, fertilizer is stored in warehouses or trucked directly to farms by LIPCO trucks.

## NOTES ON THE POTATO CROP IN CANADA

Planting of potatoes was almost complete by June 1 in Canada. The early crop has grown well and harvesting of early whites in British Columbia commenced the third week in June with shipments in volume to markets in the prairie provinces.

In southern Ontario harvesting of the early crop is well under way, with price levels below those of the corresponding week in 1956. An improvement in the market is anticipated.

With cool moist conditions in most potato growing areas, prospects as of this date are for a good crop of potatoes in Canada in 1957.

The first estimate of acreage planted will be published on August 9. In March, however, Canadian farmers indicated that they planned on planting about the same acreage this year as last, namely 304,000. In the Maritimes and Central Canada a slight increase in planting was anticipated, offsetting a slight decrease in the Prairies. If yields equal to those of the past three years materialize a crop between 60 and 70 million bushels will be forthcoming.

N. M. PARKS, *Potato Specialist*, Canada Department of Agriculture, July 12, 1957.

## CALL FOR PAPERS

The next Annual Meeting of the Potato Association of America will be held at the United States Department of Agriculture Plant Industry Station, Beltsville, Maryland, December 2, 3 and 4, 1957.

Please send titles of papers to be presented at the annual meeting to W. J. Hooker, Department of Botany and Plant Pathology, Michigan State University, East Lansing, Michigan, by October 15. Include approximate time required to present papers, and if illustrated the size of slides to be used, also names and official addresses of authors as you wish them to appear in the program. It is customary to have mimeographed abstracts of these papers for distribution to the members at the annual meeting. For that reason, the abstracts should accompany the title of the paper. Otherwise, mimeographed abstracts of your paper may not be available for distribution. Abstracts should be limited to approximately 100 words.

Good papers dealing with potato quality, storage, transportation problems and marketing are especially encouraged.

Your cooperation in sending in titles early thus making it possible for the mimeographing of abstracts and preparation and printing of programs will be greatly appreciated. Titles received after the deadline may not be accepted. Please bring this notice to the attention of your students and colleagues.

The back log of papers for publication in the American Potato Journal is low. Relatively prompt publication of papers will be possible if manuscipts are submitted immediately following presentation of the paper.

W. J. HOOKER, *Secretary*

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## SELF-POWERED TAIL LIGHT

A unique tail light, powered by its own 100-hour battery, is a new, essential night safety accessory for trailers, wagons, machinery, and equipment hauled by auto or truck. Designed by the Burgess Battery Company, Freeport, Illinois, the "Trailer-Lite" eliminates necessity of wiring into the ignition system of auto, trucks, and tractors, and guards against night time rear-end collisions. Operated by a self-contained switch, the unbreakable red tail light is easily mounted at the rear end of any trailer. Weatherproof lead wire and two insulated screw caps connect it to a newly engineered double powered steel encased battery which is mounted to the bottom or side of the trailer or hauling rig. The compact, leakproof and weatherproof battery incorporates two 6-volt batteries in a new unified battery-and-case which lasts nearly four times the life of an ordinary 6 volt battery.

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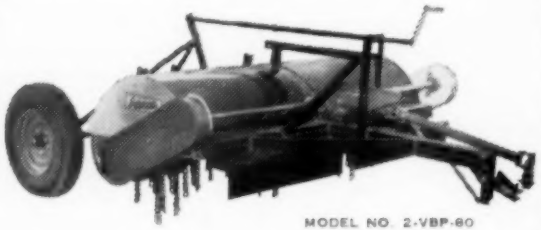

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